MEMS-Based Frequency-Tunable Reflect-Line Phase Shifter

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Abstract. This paper presents a reflect-line phase shifter with a frequency reconfigurable behaviour. The proposed design approach uses Metal-Insulator-Metal (MIM) capacitors as loads of a branch-line coupler. The reconfigurability is obtained by means of RF-MEMS switches. Results referring to a 90° differential phase shifter able to work at two different frequencies (7.7 GHz and 9.76 GHz) are reported and discussed. It will be shown that the use of RF-MEMS switches combined with MIM capacitors results in compact dimensions and good performance in terms of bandwidth, thus demonstrating that the proposed approach is an optimum candidate for designing frequency reconfigurable phase shifters.

1. Introduction

Microwave Phase Shifters (PSs) are key elements of modern telecommunication systems [1], [2]. On the other hand, devices with a frequency reconfigurable behaviour are desirable. Accordingly, in this paper we present a reflection-type differential PS whose operating frequency can be tuned by means of RF-MEMS switches. The architecture of the proposed device is illustrated in Fig. 1: it consists of a 3-dB Branch Line Coupler (BLC) terminated with MIM-capacitors [3], [4]. Both the BLC and the MIM loads have been designed with a frequency reconfigurable behaviour.

In the literature, several approaches are available for designing BLCs with a reconfigurable frequency response [5]-[7]; among these, in [7] the electrical length of the BLC arms is modified by means of four varactor diodes. In this paper, in order to tune the BLC working frequency, MEMS switches in series with MIM capacitors are used instead of varactors (see Fig. 2a). Similarly, each load of the BLC coupled ports consists of a MIM capacitor selected by means of MEMS switches. Fig. 1 shows the schematic corresponding to the application of the proposed approach in order to design a differential PS with two possible operating frequencies; it can be observed that eight MIM capacitors, each one selected by a series MEMS switch, have been used. Similarly, N possible operating frequencies can be obtained by using 6-N 4 MIM capacitors and the same number of series MEMS switches.

2. Simulated Risults

As an example of application of the proposed approach, we design a PS able to exhibit a 90° differential phase shift at two different frequencies: 9.76 GHz and 7.33 GHz. Referring to Fig. 1, we first optimized the MIM capacitances from C_1 to C_4 in order to ensure the BLC frequency reconfigurabilty; consequently, we optimized the MIM capacitances from C_5 to C_8 in order to ensure the 90° Differential Phase Shift (DPS). More in detail, C_5 and C_7 determine the DPS at 9.76 GHz, whereas C6 and C8 determine the DPS at 7.33 GHz.

The schematic obtained this way has been implemented in coplanar waveguide technology on a 525 μm high-resistivity Silicon substrate within the 8-masks MEMS realization process available at FBK laboratories [8]. The corresponding layout is illustrated in Fig. 2a; the insert shows the dimensions of the series MEMS switches which have been designed according to the process described in [8]. Table 1 summarizes the switch configurations at the two operating frequencies. The layouts corresponding to these configurations have been analysed by means of full-wave simulations; results obtained this way are given in Figs. 3-4.

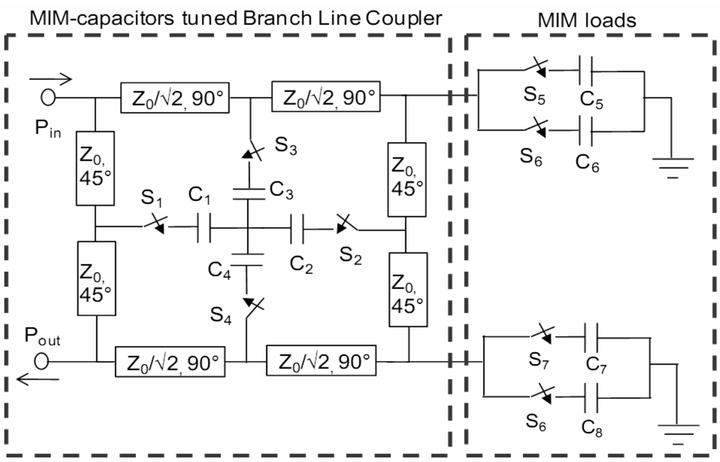

Fig. 1. Schematic representation of the proposed frequency reconfigurable PS.

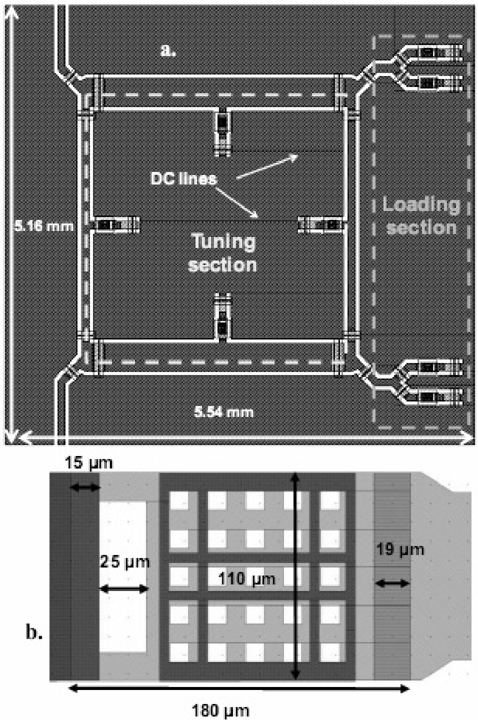

Fig. 2. Layout of the proposed frequency tunable PS (a.). MEMS switch layout and dimensions (b.).

It is evident that good performance have been obtained at both working frequencies.

The calculated differential phase shift is 90.024° at 9.76 GHz (relative phase error equal to 0.03%) and 89.716° at 7.33 GHz (relative phase error equal to 0.3%). Furthermore, from Fig. 2a it can be noticed that the proposed device occupies a very compact area (5.54×5.16 mm^2).

Table 1. Combination of the switch configurations Corresponding to the two working frequencies.

Switch	**Frequency**	
	9.76 [GHz]	**7.33 [Ghz]**
S_1	Off	On
S_2	Off	On
S_3	Off	On
S_4	Off	On
S_5	On/Off	Off
S_6	Off	On/Off
S_7	On/Off	Off
S_8	Off	On/Off

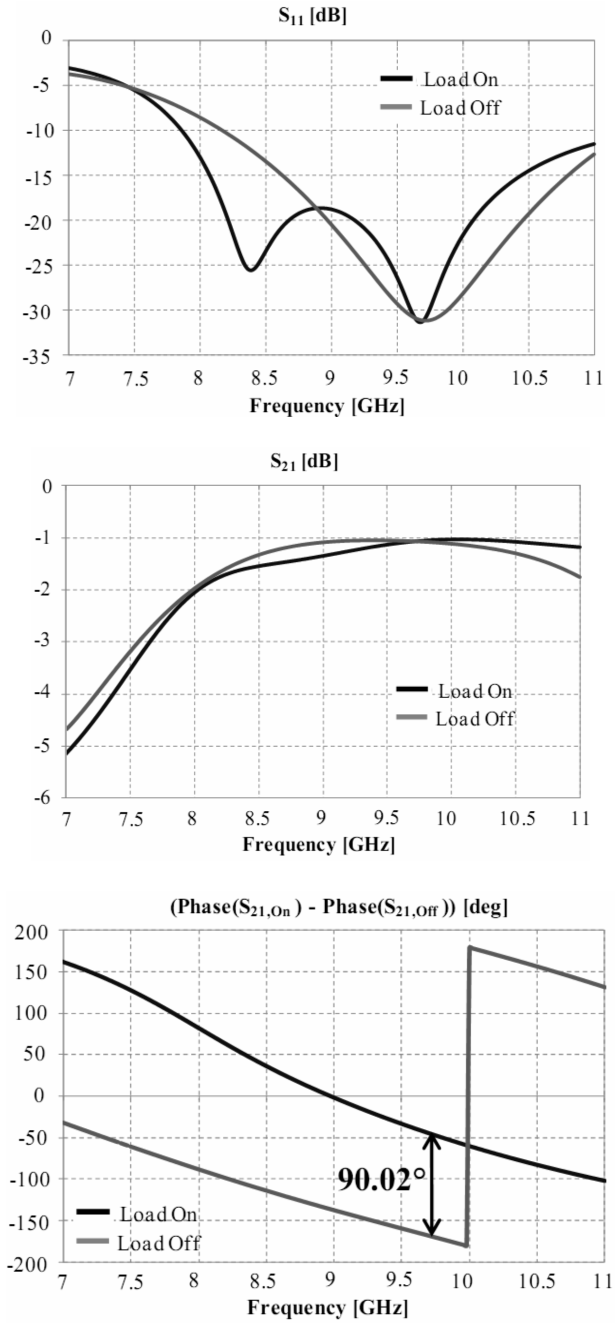

Fig. 3. Numerical results calculated for the proposed PS when the switch combination is the one corresponding to the 9.76 GHz operating frequency.

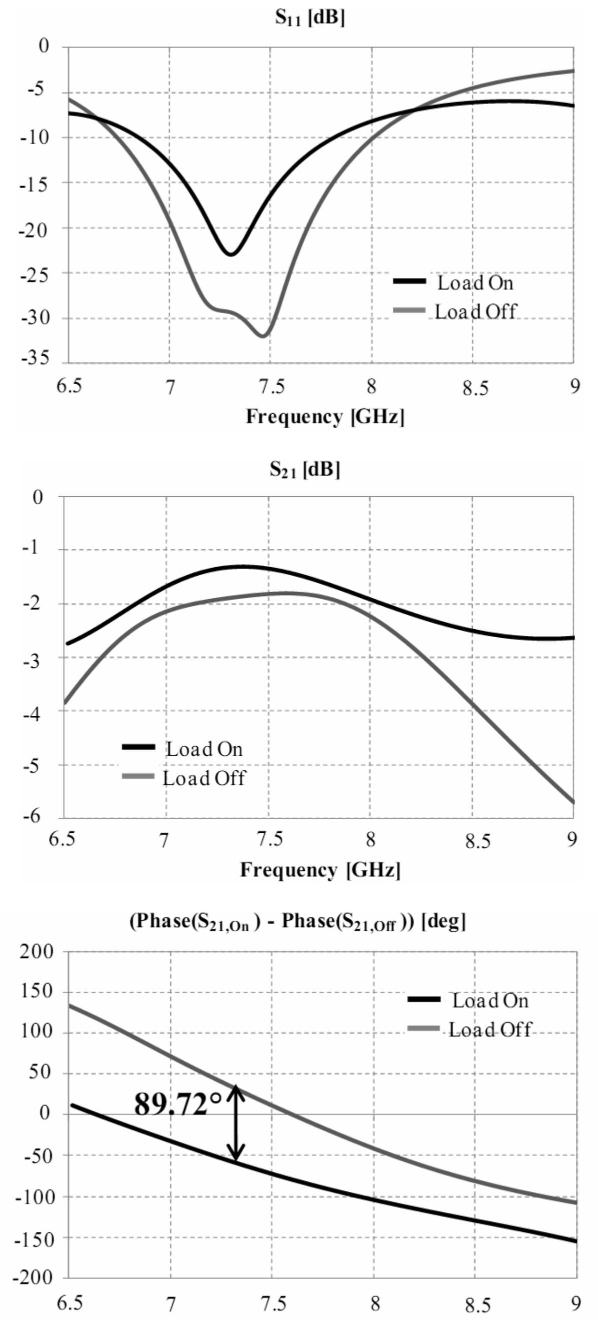

Fig. 4. Numerical results calculated for the proposed PS when the switch combination is the one corresponding to the 7.33 GHz operating frequency.

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